[preprint]aastex Vibrationally-Excited Molecular Hydrogen in Cooling Flows Donahue et al. = 15.0 truecm

$\lesssim \gtrsim H\alpha$ Lyman-α erg $s^{-1}\,cm^{-2}$ $\mathrm{erg\,s^{-1}\,cm^{-2}\,arcsec^{-2}}$ $\mathrm{erg\,s^{-1}\,cm^{-2}\,sr^{-1}\,Hz^{-1}}$ $\mathrm{phot\,s^{-1}\,cm^{-2}}$$et al.$ $\mathrm{erg\,s^{-1}}$$\chi^2$ $\mathrm{km\,s^{-1}}$ $\sim \dot{M}$

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HST Observations of Vibrationally-Excited Molecular Hydrogen in Cluster Cooling Flow Nebulae Based on observations with the NASA/ESA Hubble Space Telescope, obtained at the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc. (AURA), under NASA contract NAS5-26555

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abstract We report the results of Hubble Space Telescope NICMOS and WFPC2 imaging of emission-line nebulae in the central galaxies of three clusters of galaxies purported to host massive cooling flows, Perseus (NGC1275), Abell 2597, and PKS0745-191. The spectral signature of vibrationally-excited molecular hydrogen has been seen in every galaxy searched thus far that is central to a cluster cooling flow with an optical emission line nebula. With the exquisite spatial resolution available to us with the Hubble Space Telescope, we have discovered that the vibrationally-excited molecular hydrogen gas extends several kpc from the centers of Abell 2597 and PKS0745-191, while the vibrationally-excited molecular hydrogen in NGC1275 appears to be mostly confined to its nucleus, with some extended emission < 1 kpc from the center. The molecular hydrogen in Abell 2597 and PKS0745-191 seems to be nearly co-spatial with the optical emission-line filaments in those systems. There may be a tiny jet visible in the 1.6 μm image of PKS0745-191. We also find significant dust absorption features in the 1.6 μm images of all three systems. The dust lanes are not strictly co-spatial with the emission-line filaments, but are aligned with and perhaps intermingled with them. The morphology of the emission-line systems suggests that the presence of vibrationally-excited molecular hydrogen is not purely an AGN-related property of cluster "cooling-flow" nebulae, and that the optical and infrared emission-line gas, that is, the ionized and vibrationally-excited molecular gas have similar origins, if not also similar energy sources. The infrared molecular hydrogen lines are much too bright to be generated by gas simply cooling from a cooling flow; furthermore, the gas, because it is dusty, likely did not condense from the hot intracluster medium (ICM). We examine some candidates for heating the nebulae, including X-ray irradiation by the ICM, UV fluorescence by young stars, and shocks. UV heating by young stars provides the most satisfactory explanation for the H_2 emission in A2597; X-ray irradiation is energetically unlikely and strong shocks (v40 km s^{-1}) are ruled out by the high H_2/Hα ratios. If UV heating is the main energy input, a few billion solar masses of molecular gas is present in A2597 and PKS0745-191. UV irradiation models predict a significant amount of $1.0 - 2.0$ micron emission line from higher excitation H_2 transitions and moderate far infrared luminosities ($\sim 10^{44} h^{-2}$) for A2597 and PKS0745-191. Even in the context of UV fluorescence models, the total amount of H_2 gas and star formation inferred from these observations is too small to account for the cooling flow rates and longevities inferred from X-ray observations. We note an interesting new constraint on cooling flow models: the radio sources do not provide a significant amount of shock heating, and therefore they cannot counterbalance the cooling of the X-ray gas in the cores of these clusters.

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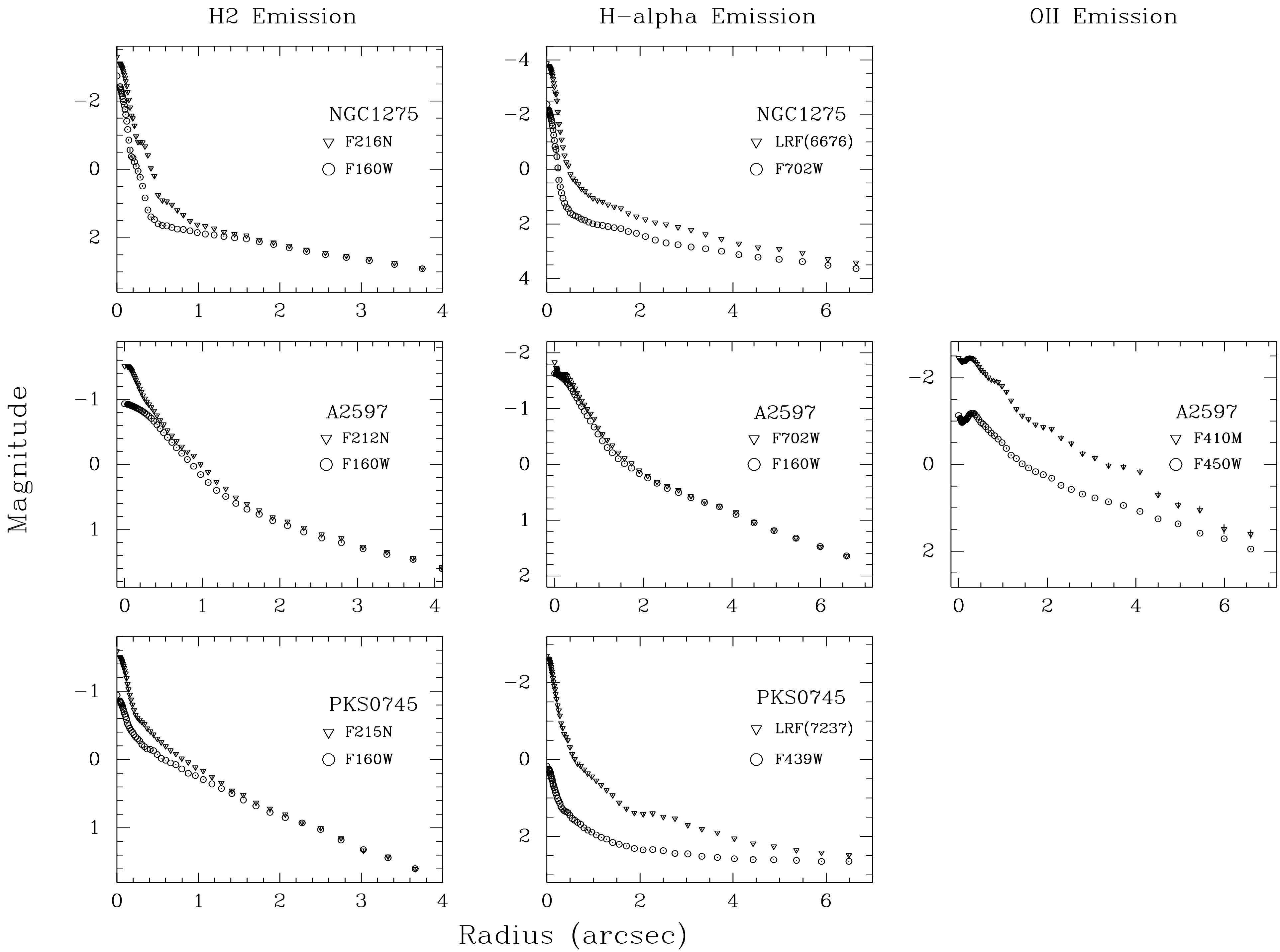
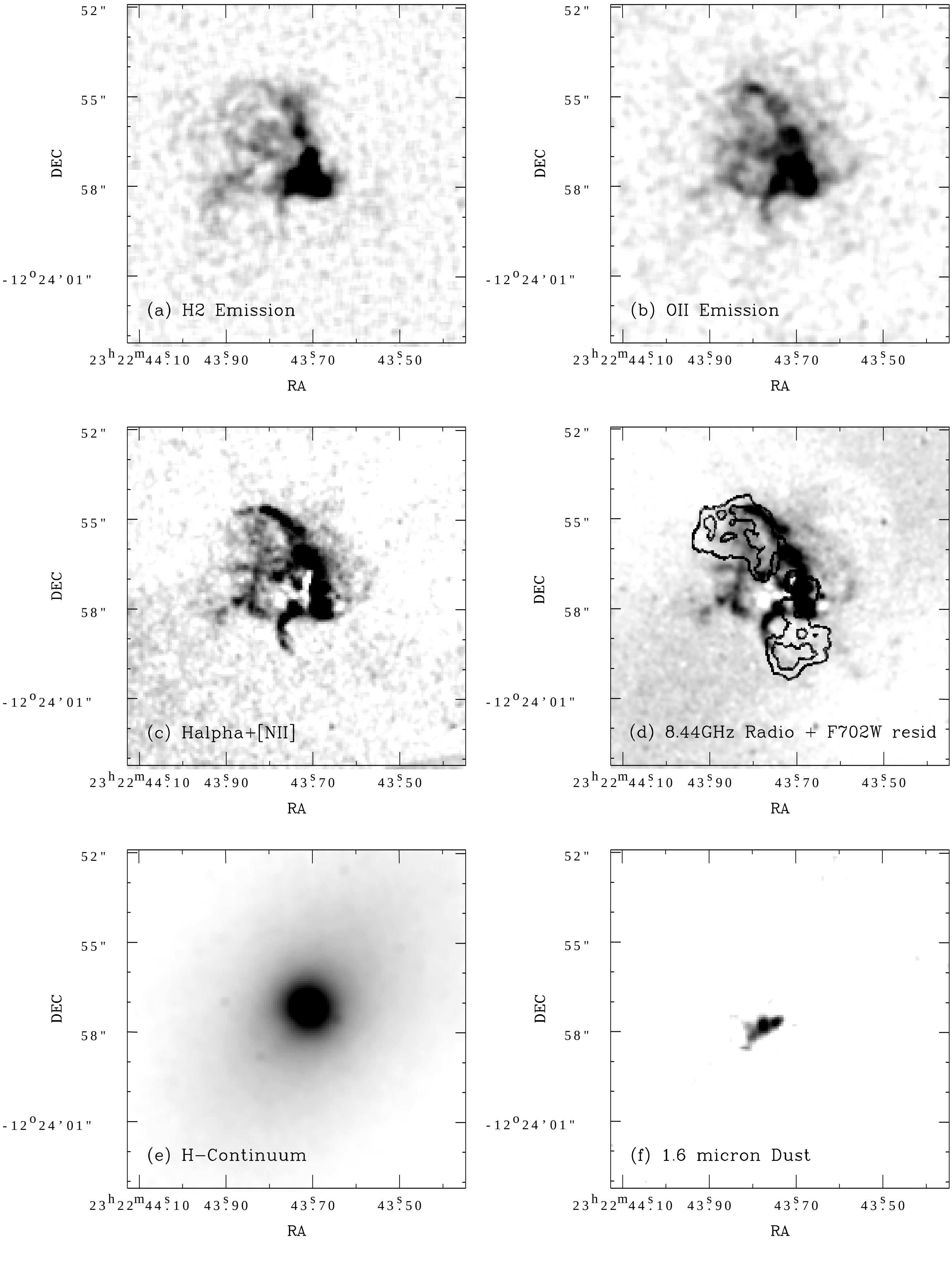


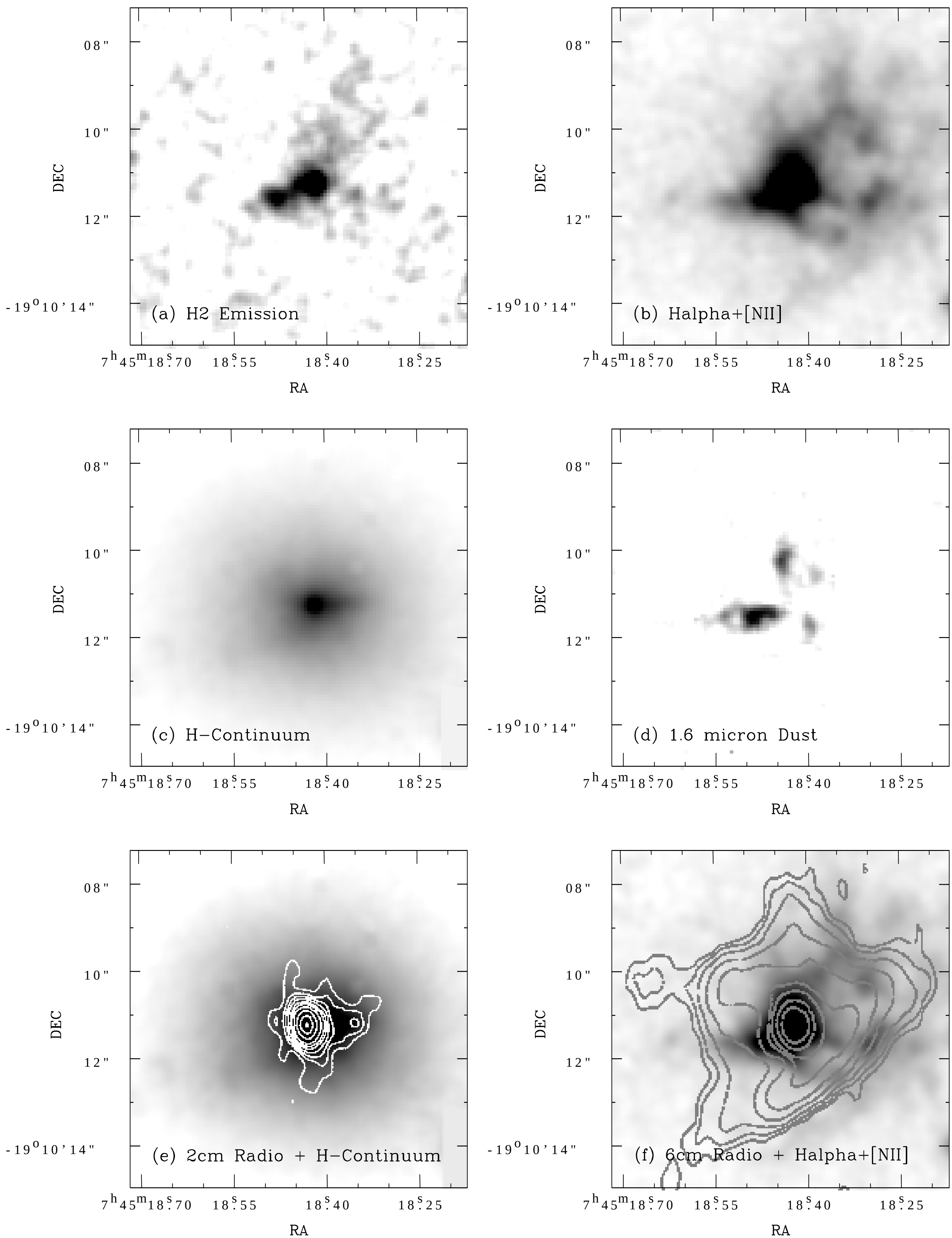
H2 Emission
H-alpha Emission
OII Emission
NGC1275
F216N
F160W
LRF(6676)
F702W
A2597
F212N
F160W
F702W
F160W
F410M
F450W
PKS0745
F215N
F160W
LRF(7237)
F439W
Magnitude
Radius (arcsec)

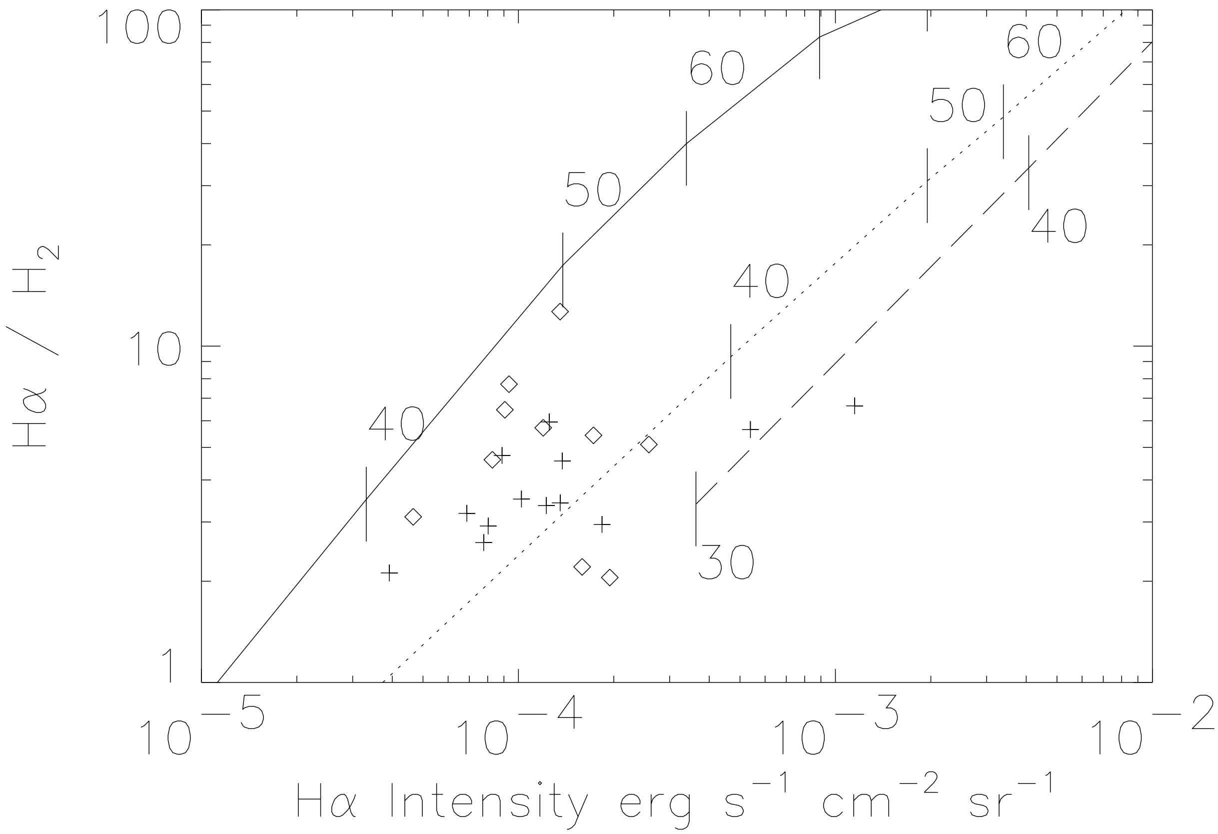
A2597



52"
55"
58"
$-12^{o}24'01"$
DEC
(a) H2 Emission
(b) OII Emission
(c) Halpha+[NII]
(d) 8.44GHz Radio + F702W resid
(e) H−Continuum
(f) 1.6 micron Dust
$23^{h}22^{m}44\overset{s}{.}10$
$43\overset{s}{.}90$
$43\overset{s}{.}70$
$43\overset{s}{.}50$
RA

PKS0745−191


(a) H2 Emission
(b) Halpha+[NII]
(c) H−Continuum
(d) 1.6 micron Dust
(e) 2cm Radio + H−Continuum
(f) 6cm Radio + Halpha+[NII]
DEC
RA
08"
10"
12"
-19°10'14"
7h45m18.s70
18.s55
18.s40
18.s25



100
10
1
10^{-5}
10^{-4}
10^{-3}
10^{-2}
Hα / H_2
Hα Intensity erg s^{-1} cm^{-2} sr^{-1}
40
50
60
40
50
60
30
40